

**REMARKS**

Claims 1-9 are pending herein. The PTO indicated that claims 2-5 and 7-9 are allowable. Claims 1, 3-5, 8 and 9 have been amended for clarification purposes only.

Applicants appreciate the PTO's indication that claims 2-5 and 7-9 would be allowed if rewritten in independent form. For the reasons explained below, however, original independent claim 1 is believed to be allowable over the applied prior art of record.

1. The PTO objected to Fig. 3 in paragraph 3 of the Office Action. The PTO is apparently arguing that the abscissa and mantissa of the graph shown in Fig. 3 are not correctly labeled. With reference to the brief description of Fig. 3, that figure depicts a chromaticity diagram, which is used to define color gamuts or color ranges and illustrates the effect of adding colors together. The CIE (an International Commission) introduced the chromaticity diagram in 1931 as an international standard for primary colors (see the attached literature reference).

It is respectfully submitted that the abscissa and mantissa of the chromaticity diagram shown in Fig. 3 are correctly labeled as evidenced by the attached CIE literature reference and Matsubara (the applied prior art of record, discussed below). For example, Figs. 7 and 19 of Matsubara show substantially similar depictions of the above-discussed CIE chromaticity diagram shown in Fig. 3 of the present application.

In view of the foregoing, reconsideration and withdrawal of the drawing objection are respectfully requested.

2. The objection to the title is noted, but deemed moot in view of the new title submitted above.

3. The objection to claim 3 is noted, but deemed moot in view of rewritten claim 3 submitted above.

4. Claims 1 and 6 were rejected under §102(b) over Matsubara et al. This rejection is respectfully traversed.

Pending independent claim 1 recites that a Group II-VI semiconductor compound first epitaxial layer group, which emits a yellow color light, is provided on a substrate. A Group II-VI semiconductor compound second epitaxial layer group, which emits a blue color light, is also provided on the substrate.

Fig. 5 of Matsubara shows that a substrate-flourescent LED has an epitaxial emission structure (i.e., active layer) including epitaxial film layers 21-25 positioned on an impurity-doped (e.g., I+Cu) n-ZnSe substrate 20. Matsubara discloses that while the epitaxial emission structure emits 480nm blue light, the n-ZnSe substrate emits 630nm red light (see Matsubara page 9, paragraph [0084]). Accordingly, Matsubara's substrate-flourescent LED emits pink or red light (see Matsubara page 10, paragraph [0087]).

The PTO is apparently alleging that Matsubara's n-ZnSe substrate 20 includes multiple epitaxial layers and corresponds to the claimed first epitaxial layer group. Although Matsubara's substrate appears to be formed from a Group II-VI compound (i.e., ZnSe), there is no disclosure or suggestion in Matsubara evidencing that n-ZnSe substrate 20 includes multiple epitaxial layers and is "provided on" a substrate, as recited in pending claim 1. The §102(b) rejection over Matsubara is erroneous for this reason alone.

Moreover, even if Matsubara's n-ZnSe substrate 20 were to be construed to correspond to the claimed first epitaxial layer group, n-ZnSe substrate 20 would emit 630nm red light, and not yellow light as claimed (see Matsubara page 9, paragraph [0084]).

In view of all of the foregoing, reconsideration and withdrawal of the §102(b) rejection over Matsubara are respectfully requested.

If the Examiner believes that contact with Applicants' attorney would be advantageous toward the disposition of this case, the Examiner is herein requested to call Applicants' attorney at the phone number noted below.

The Commissioner is hereby authorized to charge any additional fees associated with this communication or credit any overpayment to Deposit Account No. 50-1446.

Respectfully submitted,



Stephen P. Burr  
Reg. No. 32,970

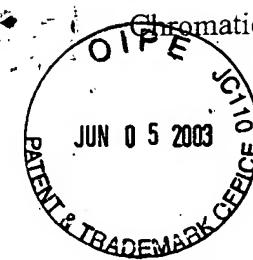
SPB/SC/tlp

Attachments:

- Appendix A- Substitute specification
- Appendix B- Marked-up copy of original specification
- CIE Chromaticity Diagram literature reference

BURR & BROWN  
P.O. Box 7068  
Syracuse, NY 13261-7068

Customer No.: 025191  
Telephone: (315) 233-8300  
Facsimile: (315) 233-8320



# CIE Chromaticity Diagram

This is an international standard for primary colors established in 1931. It allows all other colors to be defined as weighted sum of the three "primary" colors. There are no real three colors that can be combined to give all possible colors. Therefore the standard "primary" colors established by CIE don't correspond to real colors.

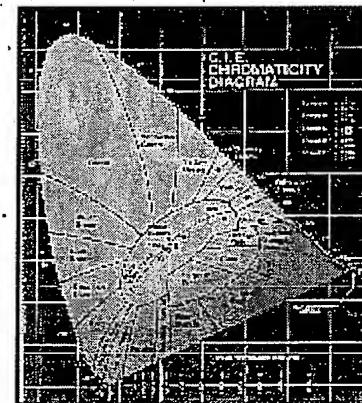
So the 3 "primary" colors are the virtual colors A, B, and C. Then for a given real color, its components with respect to the primaries are as follows:

$$x = A/(A+B+C)$$

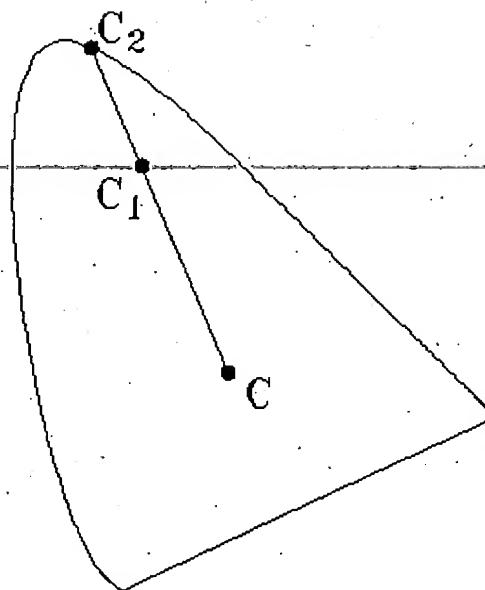
$$y = B/(A+B+C)$$

$$z = C/(A+B+C)$$

Since  $x + y + z = 1$ , if x and y are known then z can be determined.

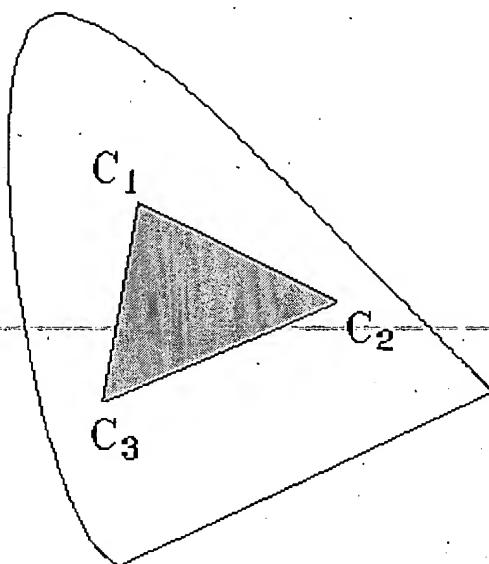


The CIE diagram is a plot of X vs. Y for all visible colors.



C corresponds to white light. For a color C1, the dominant wavelength is C2. The purity equals line length (C1-C) / line length (C-C2). The color gamut is the range of colors from C1 to C2.

For three colors, the color gamut is the triangle that encompasses the entire area, so any 3 real colors can't generate all colors.



The pigments in the human eye have peak sensitivities at about 650 nm (red), 530 nm (green), and 425 nm (blue).



[Main Color page](#)



[HyperGraph Home page.](#)

*Last changed June 15, 1999, G. Scott Owen, [owen@siggraph.org](mailto:owen@siggraph.org)*



## SEMICONDUCTOR LIGHT-EMITTING ELEMENT

### Background of the invention

#### Field of the invention

**[0001]** This invention relates to a semiconductor light-emitting element, particularly a multilayered light-emitting element to generate and emit a white color light which is composed of plural epitaxial layers grown on a substrate.

#### Related Art Statement

**[0002]** Recently, an attention is paid to a blue color light-emitting element made of III-V semiconductor compounds or II-VI semiconductor compounds, and in reality, a GaN-based semiconductor light-emitting element and a ZnSe-based semiconductor light-emitting element are developed as such a blue color light-emitting element. In addition, a white color light-emitting element is also proposed by taking advantage of the blue color light-emitting element.

**[0003]** For example, in "Optic Functional Material's Manual", p457, June, 1997, published by Optronics Ltd., such a white color light-emitting element as composed of a GaInN-based LED including a sapphire single crystal and an active layer made of GaInN and a YAG fluorescent substance is disclosed.

**[0004]** Moreover, in Japanese Laid-open Patent Publication Kokai Hei 2000-49374 (JP A 2000-49374), such a white color light-emitting element as to generate and emit a white color light by superimposing a blue color light or a blue-green color light emitted from a GaInN-based active layer and a yellow color light from the fluorescent color center of a GaN substrate which is excited by the blue color light or the blue-green color light, is

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**  
**Appendix B**

disclosed.

**[0005]** In this manner, various white color light-emitting elements using GaN-based blue color light-emitting elements are proposed, but white color light-emitting elements using ZnSe-based blue color light-emitting elements are ~~not almost scarcely~~ proposed, and thus, strongly desired.

#### Summary of the Invention

**[0006]** It is an object of the present invention to provide a new white color light-emitting element made of II-VI semiconductor compounds such as ZnSe-based semiconductor compounds.

**[0007]** For achieving the above object, this invention relates to a semiconductor light-emitting element comprising:

a substrate,

a first epitaxial layer group to emit a yellow color light which is provided on the substrate and made of II-VI semiconductor compounds, and

a second epitaxial layer group to emit a blue color light which is provided on the substrate and made of II-VI semiconductor compounds.

**[0008]** As mentioned above, in the present invention, on a substrate are provided and stacked a first epitaxial layer group and a second epitaxial layer group which are made of II-VI semiconductor compounds. Then, a yellow color light is generated and emitted from the first epitaxial layer group and a blue color light is generated and emitted from the second epitaxial layer group. Therefore, by superimposing the yellow color light and the blue color light, a given white color light can be obtained from the semiconductor light-emitting element entirely.

#### **VERSION WITH MARKINGS TO SHOW CHANGES MADE**

#### **Appendix B**

[0009] In this case, by controlling the chromaticities and the intensities of the yellow color light and the blue color light independently, various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the combination of the yellow color light and the blue color light. As a result, a much brighter white color light can be obtained in the semiconductor light-emitting element than in a conventional one.

#### Brief Description of the Drawings

For better understanding of the present invention, reference is made to the attached drawings, wherein

Fig. 1 is a structural view showing a semiconductor light-emitting element according to the present invention,

Fig. 2 is a structural view showing another semiconductor light-emitting element according to the present invention,

Fig. 3 is a graph showing the relation between the chromaticity and the bandgap in a II-VI semiconductor compound,

Fig. 4 is a graph showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound,

Fig. 5 is another graph showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound,

Fig. 6 is a structural view showing a first epitaxial layer group, and

Fig. 7 is a structural view showing a second epitaxial layer group.

#### Detailed Description of the Invention Preferred Embodiments

[0010] This invention will be described in detail with reference to the accompanying

#### **VERSION WITH MARKINGS TO SHOW CHANGES MADE**

#### **Appendix B**

drawings.

[0011] Fig. 1 is a structural view showing a semiconductor light-emitting element according to the present invention, and Fig. 2 is a structural view showing another semiconductor light-emitting element according to the present invention.

[0012] Figs. 1 and 2 show semiconductor light-emitting elements 10 and 20, each of which include substrates 1, first epitaxial layer groups 3 as a yellow color light-emitting elements via first buffer layers 2, and second epitaxial layer groups 5 as blue color light-emitting elements via second buffer layers 4, respectively.

[0013] On the second epitaxial layer group 5 are is provided a p-type contact electrode device 6, respectively, and on the exposed surfaces of the second buffer layers 4 are is provided a p-type electrodes 7, respectively. In addition, in the semiconductor light-emitting element 10, on the exposed surface of the first buffer layer 2 is provided an n-type electrode 8, and in the semiconductor light-emitting element 20, on the backside surface of the substrate 1 is provided another n-type electrode 8.

[0014] In either case, by applying a given voltage between the p-type contact electrode device 6; the p-type electrode 7 and the n-type electrode 8, to flow an electric current through the first epitaxial layer group 3 and the second epitaxial layer group 5, the first epitaxial layer group 3 and the second epitaxial layer group 5 are excited, to and generate and emit a yellow color light and a blue color light, respectively. In the semiconductor light-emitting element 10 or 20, the yellow color light and the blue color light are superimposed and thus, a given white color light is generated and emitted.

[0015] The yellow color light and the blue color light are generated and emitted from the first epitaxial layer group 3 and the second epitaxial layer group 5, independently.

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**  
**Appendix B**

Therefore, by controlling the chromaticities and the intensities of the yellow color light and the blue color light independently, various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the combination of the yellow color light and the blue color light. As a result, a much brighter white color light can be obtained in the semiconductor light-emitting element than in a conventional one.

[0016] Fig. 3 is a graph showing the relation between the chromaticity and the bandgap in a II-VI semiconductor compound, and Figs. 4 and 5 are graphs showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound, respectively.

[0017] In order to obtain a white color light from the combination of the yellow color light and the blue color light, the inventors investigated the constructions of the first epitaxial layer group 3 and the second epitaxial layer group 5 on the basis of the graphs shown in Figs. 3-5.

[0018] Fig. 6 is a structural view showing a first epitaxial layer group. In Fig. 6, the first epitaxial layer group 3 includes an n-type cladding layer 3-1, an n-type optical waveguide layer 3-2 provided on the n-type cladding layer 3-1, and a light-emitting active layer 3-3 provided on the n-type optical waveguide layer 3-2. Moreover, the first epitaxial layer group 3 includes a p-type optical waveguide layer 3-4 provided on the light-emitting active layer 3-3 and a p-type cladding layer 3-5 provided on the p-type optical waveguide layer 3-4.

[0019] Electrons and positive holes are injected into the light-emitting active layer 3-3 from the n-type optical waveguide layer 3-2 and the p-type optical waveguide layer 3-4,

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**  
**Appendix B**

respectively, and are combined, to emit a given color light.

[0020] The n-type cladding layer 3-1 and the p-type cladding layer 3-5 function as barrier layers for the light-emitting active layer 3-3.

[0021] In view of Figs. 3-5, it is desired that the light-emitting active layer 3-3 is made of a II-VI semiconductor compound including Zn, Se, Te and Cd, particularly having a composition of  $Zn_{1-x}Cd_xSe_{1-y}Te_y$  ( $0.01 < x \leq 0.4$ ,  $0.01 < y < 0.4$ ). In this case, since the  $Zn_{1-x}Cd_xSe_{1-y}Te_y$  semiconductor material has a bandgap energy within 2.132-2.172eV, it can generate and emit a yellow to yellow green color light stably if it is excited.

[0022] The n-type cladding layer 3-1, the p-type cladding layer 3-5, the n-type optical waveguide layer 3-2 and the p-type optical waveguide layer 3-4 are made of normal II-VI semiconductor compounds, respectively. In the case of the light-emitting active layer 3-3 being made of the above-mentioned semiconductor material, it is desired that the n-type cladding layer 3-1 through the p-type optical waveguide layer 3-4 are made of II-VI semiconductor compounds including Be and Mg, particularly having a composition of  $(BeMgZn)Se$ .

[0023] Fig. 7 is a structural view showing a second epitaxial layer group. In Fig. 7, a second epitaxial layer group 5 includes an n-type cladding layer 5-1, an n-type optical waveguide layer 5-2 provided on the n-type cladding layer 5-1 and a light-emitting active layer 5-3 provided on the n-type optical waveguide layer 5-2. Moreover, the second epitaxial layer group 5 includes a p-type optical waveguide layer 5-4 provided on the light-emitting active layer 5-3 and a p-type cladding layer 5-5 provided on the p-type optical waveguide layer 5-4.

[0024] Electrons and positive holes are injected into the light-emitting active layer 5-3

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**  
**Appendix B**

from the n-type optical waveguide layer 5-2 and the p-type optical waveguide layer 5-4, respectively, and are combined, to emit a given color light from the light-emitting active layer 5-3.

**[0025]** The n-type cladding layer 5-1 and the p-type cladding layer 5-5 function as barrier layers for the light-emitting active layer 5-3.

**[0026]** In view of Figs. 3 and 5, the light-emitting active layer 5-3 is made of a II-VI semiconductor compound including Zn, Cd, Se and Be. Moreover, in view of Figs. 3 and 4, the light-emitting active layer 5-3 may be made of a II-VI semiconductor compound including Zn, Se, Te and Cd, particularly having a composition of  $Zn_{1-Z}Cd_zSe_{1-V}Te_V$  ( $0 < Z < 0.1$ ,  $0 < V < 0.1$ ). In this case, since the  $Zn_{1-Z}Cd_zSe_{1-V}Te_V$  semiconductor material has a bandgap energy within 2.528-2.675eV, it can generate and emit a blue green to blue color light stably if it is excited.

**[0027]** The n-type cladding layer 5-1, the p-type cladding layer 5-5, the n-type optical waveguide layer 5-2 and the p-type optical waveguide layer 5-4 are made of normal II-VI semiconductor compounds, respectively. In the case of the light-emitting active layer 5-3 being made of the above-mentioned semiconductor material, it is desired that the n-type cladding layer 5-1 through the p-type optical waveguide layer 5-4 are made of II-VI semiconductor compounds including Be and Mg, particularly having a composition of  $(BeMgZn)Se$ .

**[0028]** In the first and the second epitaxial layer groups 3 and 5, the light-emitting active layers 3-3 and 5-3 may be made of single layers or quantum dots, respectively. If the light-emitting active layers 3-3 and 5-3 are made such quantum dots, the mismatches in lattice constant of the layers 3-3 and 5-3 can be mitigated.

[0029] If the first buffer layer 2 and the second buffer layer 4 are made of ZnSe semiconductors, the mismatches in lattice constant between the semiconductor layers constituting the semiconductor light-emitting elements 10 and 20 as shown in Figs. 1 and 2 can be mitigated.

[0030] In the semiconductor light-emitting elements 10 and 20, the p-type contact electrode device 6 may be made of a p-type BeTe contact layer/p-type ZnSe cap layer/p-type layer electrode.

[0031] The p-type electrodes 7 and the n-type electrodes 8 may be made of normal electrode materials, respectively.

[0032] The substrates 1 may be made of normal substrate materials available by persons skilled in the art, particularly made of a GaAs substrate or a InP substrate.

[0033] Although the present invention was described in detail with reference to the above examples, this invention is not limited to the above disclosure and every kind of variation and modification may be made without departing from the scope of the present invention.

[0034] For example, in the semiconductor light-emitting elements 10 and 20 as shown in Figs. 1 and 2, the first epitaxial layer group 3 as a yellow light-emitting element is provided on the downside, and the second epitaxial layer group 5 as a blue light-emitting element is provided on the upside. However, it is possible to arrange the epitaxial layer groups the other way around, will do.

[0035] In the first epitaxial layer group 3 and the second epitaxial layer group 5 as shown in Figs. 5 and 6, the lower semiconductor layers from the light-emitting active layers 3-3 and 5-3 are made of n-type semiconductor compounds, and the upper

semiconductor layers from the light-emitting active layers 3-3 and 5-3 are made of p-type semiconductor compounds. However, it is also possible to arrange those layers the other way around, -will do.

[0036] As mentioned above, the semiconductor light-emitting element of the present invention has, on a given substrate, the first epitaxial layer group to emit a yellow color light and the second epitaxial layer group to emit a blue color light which are made of II-VI semiconductor compounds. Therefore, the semiconductor light-emitting element can generate and emit various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the combination of the yellow color light and the blue color light. As a result, a much brighter white color light can be obtained in the semiconductor light-emitting element than in a conventional one.